Measurements of Turbulence in the Upper Layer with AUTOSUB

Thomas Osborn
Olin Hall
The Johns Hopkins University
3400 N Charles Street
Baltimore, MD 21218-2681
phone (410) 516-7039 fax (410) 516-7933 email osborn@jhu.edu
Award Number: N000149910088

LONG-TERM GOALS

The long term goal is to understand the dynamics of the upper layer of the ocean.

OBJECTIVES

This grant covers measurements made in conjunction with Drs. Steve Thorpe and Rolf Lueck using AUTOSUB equipped with side scan sonars and turbulence probes to examine and quantify the following phenomena:

1. the intensity, structure and decay of turbulence beneath breaking wind waves, graded according to their acoustic scattering on breaking, in different wind, buoyancy flux, and swell conditions, to provide the information necessary to construct a model of turbulence generated by breaking waves (in the presence of a buoyancy flux), in particular to assess its effects on turbulence production in the mixed layer and transport of momentum and heat. Presently, little is known even of the vortex structure/rotors produced or the persistence of turbulence beneath breaking waves (Thorpe 1995).
2. the variation of turbulence levels within and between the bands of bubbles associated with Langmuir circulation, to establish the role of Langmuir circulation in the vertical transport of heat and momentum, comparing their effects with that of breaking waves, with the objective of improving their representation in models of air-sea transfers and the mixed layer; and
3. the variation in upper ocean turbulence resulting from internal gravity waves to establish the effect of internal waves on turbulence in the upper ocean (by, for example, the stretching of vortex lines - see Thorpe, 1996).

The first two items were objectives of the USS Dolphin experiment in 1988 (Osborn et. al., 1992) which collected some tantalizing data before the experiment was terminated as a consequence of generator failure. To achieve these objectives, AUTOSUB will operate in open waters in the vicinity of the shelf break to the west of Scotland. It is hoped, in particular, to operate in severe conditions in the winter.

APPROACH

AUTOSUB (figure 1) is funded by the Natural Environment Research Council of the United Kingdom and the operations are located at the Southampton Oceanography

Figure 1. Top panel is AUTOSUB underway for near surface test in Loch Linnhe Scotland. The lower panel shows the turbulence pressure case covered with the retractable sheath that protects the delicate probes when the vehicle is on the surface.

Centre. The vehicle is a 6.8 m long, 0.9 m in diameter, and weighs 3400 pounds in air. Propulsion is from a brushless DC motor that uses rare earth magnets on an external rotor that holds the five blades of the propeller. The present range is 70 km (soon to be extended to 1000 km) with an endurance of 10 hours (soon to be extended to 150 hours). It is presently capable of 250 m depth but can operate at 2 m depth. Operational depth will be increased to 2500 to 5000 m. Cruising speed depends on instrumentation with a nominal value of 2 m/s for a clean configuration and a speed of 1.8 m/s for our present configuration. The vessel operates very smoothly with r.m.s. values 0.04 m for depth, 0.2° for pitch, 0.2° for yaw, and 0.4° for roll.

To achieve the mission objectives, AUTOSUB is equipped with (a) ARIES II control and sonars (250 kHz at 2 Hz scan rate), (b) turbulence sensors, (c) CTD - at least 2 Hz recording (for detection of fronts, etc), and (d) 300 kHz ADCP. The CTD and ADCP are part of the normal instrumentation complement on AUTOSUB.

The turbulence instrumentation that are used in this project were originally designed and developed for the work on the USS Dolphin. They use the same electronic circuits for processing and filtering the data before digitization. The system is specifically set up for the 1.8 m/s velocity of the AUTOSUB. The digitization rate is 512 Hz and the analog filters on the data channels cut off sharply at 200 Hz. The data is digitized by, and stored in, a small computer (a Toshiba Libretto 50ct) which is located inside AUTOSUB. This technology enables us to digitize and store 20 hours worth of data on a commercially available package that is only 4.5 inches by 9 inches by 1.5 inches. The present storage capacity of this machine was sufficient for the feasibility testing. Power comes from the AUTOSUB. A timing signal comes from the ARIES II package in order to assure alignment between the two data sets.

For trials and initial testing of the system in the ocean we had eight channels of data: two shear probes (one measuring the cross stream horizontal velocity fluctuations and the other the vertical velocity component) , temperature, temperature derivative, two accelerometers (for roll and heave), pressure and pressure derivative. The shear data are be used to calculate dissipation rate. The temperature and temperature derivative data can be combined and digitally filtered (Osborn et. al., 1992) to produce high resolution temperature traces with resolution of millidegrees. This data offers the potential of calculating the turbulent heat flux just below the sea surface (Yamazaki and Osborn, 1993). When near the surface, the pressure and its derivative can be combined to produce a pressure record with sufficient resolution to resolve the wave spectra.

Airfoil probes and thermistors are, by their very nature, delicate. The operation of AUTOSUB presupposes transit of the vehicle along the surface from the launch area to the operational area. As well, the vessel surfaces occasionally to check its location with GPS. The greatest danger to the sensors comes from debris floating on the surface. Therefore, we use an automated system that deploys a protective cover over, and around, the probes when they are not in use. Figure 1 shows the system which is substantial enough to protect the probes from direct impact but retractable for measurements so as not to disturb the local flow at the sensors.

WORK COMPLETED

Phase I of the study (spring 1999) consisted of shallow water coastal proving trials in Loch Linnhe, Scotland to establish handling methodology, vibration noise levels, and interference-free, recording using the turbulence instrumentation together with the 250 kHz sonar.

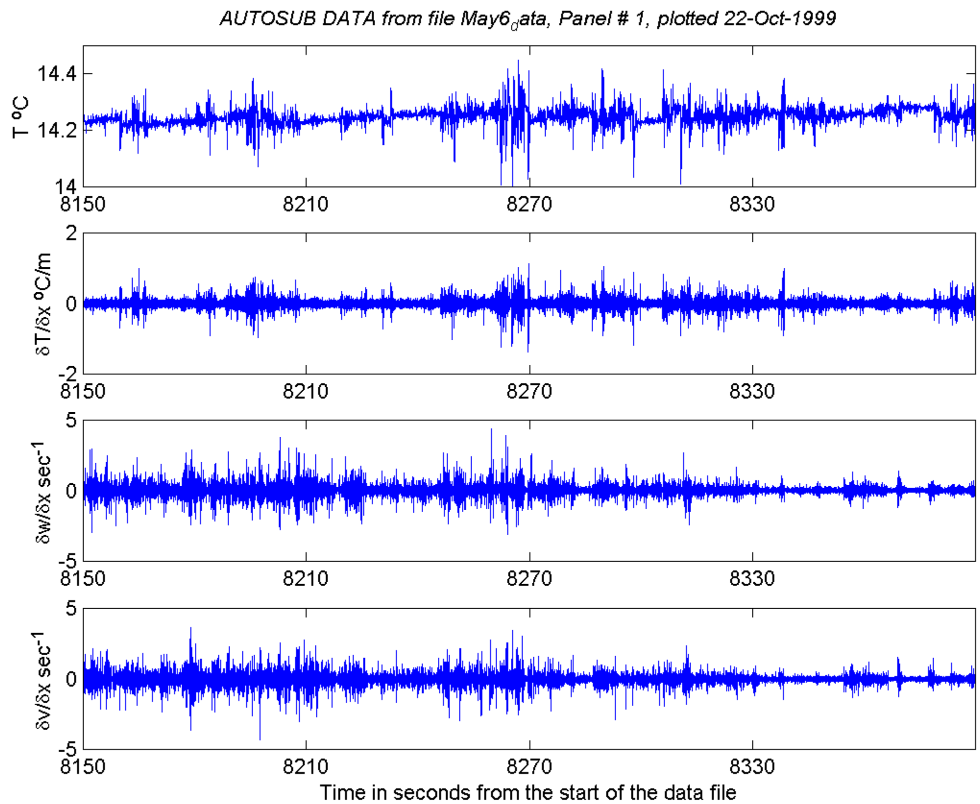
RESULTS

During the spring of 1999 there were three tests of the turbulence package with AUTOSUB.
First Trials 22-30 March in Southampton

These trials consisted of 1) laboratory checks of the functioning of the turbulence package after shipment to England, 2) bench tests of the package in conjunction with the ARIES sonar and data loggers to verify the functioning of the trigger signal to start recording, the ping count signal to align the two data series, and 3) test for electrical noise induced in the turbulence package by the ARIES sonars or recording package. Tests were then conducted with AUTOSUB in the laboratory and in fresh water. All these test went well.

Second Trials 19-21 April and third trials 2-6 May Oban

The AUTOSUB was operated for one run on 19 April with the turbulence package (one shear probe and no thermistor) and ARIES operating. Operations were not possible on the 20th due to high winds(50 knots). The data collected on the 19th looked rather promising. Further trials were undertaken in May with data collected on the 3rd, 5th, and 6th of May.



The pressure and pressure derivative channels worked. There is a bit of drift (thermal?) on the pressure data and a bit more noise than usual on the pressure derivative. There is a spiking of the record while the AUTOSUB is on the deck due to the Argos transmitter. This problem goes away when the vehicle is in the sea water and is no problem. Grounding of the power supply to the pressure transducer (see later for the reason why) induced a regular spiking noise in the pressure derivative. This noise was not associated with AUTOSUB but rather the Libretto computer and will be fixed with the replacement of the Libretto computer with an embedded computer system.

The shear data looked good initially but as the signal gets quieter there is a spiking that shows up. Discussions with AUTOSUB personnel led to the conclusion that it was the ADCP causing the problem (due to repetition rate and different ping structure for the different trials). This signal also showed up in the temperature gradient channel. Attaching a ground wire from the power supply ground to the pressure transducer cured the ADCP pickup in the shear channels and temperature gradient. There was no sign of pickup from the ADCP, ARIES, or Collision Avoidance Sonar.

Once the ground wire was installed the temperature and temperature gradient channels worked well except for the last day when there was a lot of spiking in parts of the data. The signal was consistent with an intermittent opening of the connection to the thermistor. It was not consistent with a cracked thermistor and leakage to seawater. The accelerometers worked well providing signal that enable removal of noise from the turbulence spectra (Levine and Lueck 1998).

IMPACT/APPLICATIONS

The development of a long range, autonomous capability to sample turbulence in the surface and near surface regimes of the upper ocean in difficult weather conditions will provide information on the important and complex processes that occur there.

TRANSITIONS

The technology for turbulence measurements and interpretation that has been developed by the PI through ONR funding during the last 25 years is now well established in the oceanography community.

REFERENCES

Levine, E.R. and R.G. Lueck, 1998. Turbulence measurements from an autonomous underwater vehicle. Submitted to *Journal of Atmospheric and Oceanic Technology*.

Gargett, A.E., T.R. Osborn, and P.W. Nasmyth, 1984: Local isotropy and the decay of turbulence in a stratified fluid. *J. Fluid Mechanics*, **144**, 231-280.

Mudge, T.D. and R.G. Lueck, 1994. Digital signal processing to enhance oceanographic observations, *J. Atmos. Oceanogr. Techn.*, **11**, 825-836.

Osborn, T., D.M. Farmer, S. Vagle, S. Thorpe, M. Cure, 1992. Measurements of bubble plumes and turbulence from a submarine. *Atmosphere - Ocean* **30**, 419-440.

Osborn, T., 1991. Observations of the 'Salt Fountain'? *Atmosphere-Ocean*, **29**, 340-351.

Thorpe, S.A., 1995. Dynamical processes of transfer at the sea surface. *Prog. Oceanogr*. **35**, 315-352.

Thorpe, S.A., 1996. Interactions between internal waves and boundary layer vortices. *Journal of Physical Oceanography*, **27**, 62-71.

Yamazaki, H., and T. Osborn, 1993. Direct estimation of the heat flux in the seasonal thermocline. *J. Phys. Oceanogr.* **23**(3) 503-516.